Field Test of a Mechanical Demining System On an Impact Area

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From 26 June to 29 July 2000, the U.S. Army Corps of Engineers (USACE) tested the effectiveness of the Krohn Mechanical Mine Clearance System (KMMCS) at an ordnance project at Combat Training Center, Hohenfels, Germany. The KMMCS was used to assist in the subsurface clearance of an impact area for antitank ordnance. The site had also been used as a demolition area for many other kinds of ordnance.

Several factors led to the decision to test KMMCS. Concentrations of unexploded ordnance (UXO), ordnance scrap and target scrap were much heavier in the target area than had been expected. The clearance team had spent 8 days clearing one 25- by 25-meter grid to a depth of 4 feet, removing 61 UXO items and 2450 pounds of OE scrap and target scrap. Clearly, production was falling behind and other means of clearance must be explored.

At about the same time, USACE learned of the KMMCS through another clearance effort that had been performed at Hohenfels. The proposed cost for testing the KMMCS, approximately $9700 per acre, was significantly less than the estimated cost of clearing manually. This suggested a partial solution to the production problem.

The USACE was also interested in trying innovative technology, and the customer was supportive of the effort. The owner claimed that this machine could withstand detonations of up to 22 pounds (10 kilograms) net explosive weight of TNT. The machine could till the soil and destroy surface and subsurface anomalies to a depth of approximately 1 foot. It could travel at the rate of about 1 mile per hour. Under ideal conditions this would result in a clearance rate of about 6 acres per 10-hour day. The USACE was eager to test these claims and the Corps contractor, EODT Inc., was receptive to the prospect of trying out the system.

Physical Description

The KMMCS consists of an armor plated, track driven vehicle, equipped with a front mounted tiller system that includes a roller with teeth and a thick steel shroud attached to hydraulically operated arms. Armor plating is 2.36 inches thick and protects the engine compartment, cab, and all other components except the rear-mounted radiators. The operator’s compartment is padded for sound and lined with Kevlar for added protection from fragmentation and overpressure. The roller is driven by two hydraulic motors, which are built into the roller for protection, and can be rotated clockwise or counterclockwise. The complete clearance system includes two different tiller systems, coarse and fine that can be interchanged in about 5 hours.

The coarse tiller system is intended for first and second passes and can be rotated at a rate between 80 rpm and 130 rpm. The roller is 118 inches long, approximately 24 inches in diameter, and is fitted with teeth 10 inches high and 2 inches thick. These teeth are offset on the roller to ensure complete excavation of subsurface anomalies as the machine travels forward. This offset combined with a counterclockwise rotation of the roller is designed to loosen the soil, shred vegetation, break up stones, and detonate ordnance.

The owner’s complete clearance system concept includes a second pass with a separate machine defined as the “Fine System”. The fine tiller system is intended for mincing the loosened soil and anomalies after the coarse system has completed its tilling. This system consists of two rollers mounted in tandem and is attached to the vehicle similar to the coarse system. The front roller is 10 feet long, 22 inches in diameter, and is fitted with teeth approximately 8 inches high, and 1 inch thick. These teeth are mounted closer together than the coarse system with two protrusions designed to mesh with the teeth on the rear roller.

The rear roller is 10 feet long, 12 inches in diameter and mounted approximately 20 inches behind the front roller. These teeth are mounted in pairs with a 3-inch separation designed to mesh with the front roller teeth. The front roller rotates clockwise at a rate of 120 rpm, and the second roller rotates counterclockwise at a rate of 700 rpm. These two rollers working together are designed to fine till the soil and shred all anomalies.

The owner also provided for testing purposes a smooth roller designed for detonating surface UXO, and a plow system intended to excavate items greater than 1 foot deep.

KMMCS Operation

Before the test could begin, the project work plan had to be revised and approved by the USACE. Minimum Separation Distances (MSD) were calculated based on intentional detonation of a 90 mm projectile. From the exposed front of the machine the MSD was set at 1955 feet, and from the armored sides and rear the MSD was set at 985 feet.

The KMMCS was used to till nearly 17 acres in the heaviest part of the target area to a depth of 30 cm, using both the coarse and fine tiller systems. As the KMMCS advanced with the coarse tiller, it churned up the soil and shredded vegetation. Stones, UXOs and target scrap were crushed, detonated or brought to the surface. The fine system was intended to crush the smaller UXO items.

The system’s effectiveness was assessed with regard to ability to safely withstand detonations, production rate, down time, degree of clearance, applications under differing weather conditions, and benefits to the UXO personnel who had to conduct the follow-up clearances.

Results

During the tilling operations the KMMCS initiated 36 detonations without effect on the machine or driver. The machine proved to be very effective in tilling the soil thoroughly, bringing ordnance items to the surface, and churning up all vegetation and trees less than 6 inches in diameter. OE items were much easier to spot visually on the bare surface, and were much easier to excavate because of the loosened soil.

Ground surfaces that had been very rough and uneven were significantly smoothed out by the tilling operation. This enabled the geophysical equipment to be towed much more easily and resulted in a significant improvement in data accuracy.

The system experienced significant down time for several reasons. The equipment broke down several times due to ruptured hydraulic hoses and defective parts. The equipment proved to be ineffective in wet weather, because mud would cake on the rollers. Most of the down time was due to large pieces of target scrap getting jammed in the rollers. At one point rollers had to be changed out because the teeth had worn down significantly trying to work through a rocky area of the site.

The owner had claimed that the Fine System would effectively demilitarize expended ordnance items by crushing them between the dual rollers. Tests showed that although the system was still effective in smoothing the soil after the Coarse system pass and continuing to move items to the ground surface, it was ineffective in demilitarizing ordnance items. Neither the smooth roller nor the plow system were effective for their intended applications.

Test Grid

After the Krohn machine had completed one pass over the target area with the coarse roller, a 10M x 25M test grid was set up in the center of the target area. The grid was subjected to three cycles of geophysical mapping, clearing of ordnance, and tilling with the KMMCS. This grid was strategically placed to include a portion of a grid that had been cleared by EODT, and to include a portion of a grid geophysically mapped in 1999.

After first removing all surface scrap, the site was geophysically mapped. The KMMCS then performed a second pass over the test grid using the fine roller. A third pass was made over the northern one-half of the grid with the Plow System.

The grid was again surface cleared, and a cursory subsurface removal was conducted over the grid. This subsurface removal resulted in gathering approximately 50 pounds of OE scrap. The grid was again mapped. This second mapping showed that anomalies were still too dense to pick single targets, so a third geophysical investigation was proposed. Prior to the third investigation, a subsurface clearance was conducted on the western one-half of the grid, to a depth of approximately one-foot. During this clearance, EODT investigated 430 anomalies, removed approximately 280 pounds of OE scrap, 10 pounds of target scrap, and one

81mm HE mortar.

Two geophysical profiles were mapped across the test grid that extended into the adjacent uncleared areas.

When the geophysical maps were compared, it was clear that each pass with the coarse and fine rollers had been effective in progressively exposing more ordnance for recovery.

Cost Savings

In order to determine actual cost savings, grids were selected in medium and high density areas for comparison of production rates. The following tables show ordnance clearance rates for grids that were not tilled before clearance and grids tilled prior to clearance.

Effectiveness of Tilling in Areas of Heavy Anomaly Counts (More than 1000 per grid)

Comparison Data	**Not Tilled**	**Tilled**
Grid	**A**	**B**
Man Hours	250	100
Subsurface Anomalies / Digs	2,195	1,734
Total UXO	18	5
Pounds of OE-Scrap	454	642
Pounds of Target Scrap	852	377
KMMCS cost per grid, $2.08 Per Sq M	$0	$1,300.00
*Cost Per Man Hour	$116.00 x 250 hrs	$116.00 x 100 hrs
Cost Per Grid	$29,000.00	$12,900.00
Cost Savings		$16,100.00

* Includes Material, Lodging and Per Diem spread over a 7 day period.

Effectiveness of Tilling in Areas of Medium Anomaly Counts (Less than 1000 per Grid)

Comparison Data	**Not Tilled**	**Tilled**

Grid	A	B
Man Hours	100	50
Subsurface Anomalies / Digs	595	230
Total UXO	4	1
Pounds of OE-Scrap	385	110
Pounds of Target Scrap	32	30
KMMCS cost per grid, $2.08 Per Sq M	$0	$1,300.00
*Approximate Cost Per Man Hour	$116.00 x 100 hrs	$116.00 x 50 hrs
Approximate Cost Per Grid	$11,600.00	$7,100.00
Cost Savings		$4,500.00

* Includes Material, Lodging and Per Diem spread over a 7 day period.

The following table shows the potential cost savings that could be realized for the entire project by tilling the grids prior to clearance.

Total Potential Cost Savings

No. of Contacts	Cost Savings per Grid	Number of Grids	Cost Savings
More than 1000	$16,000	27	$432,000
Less than 1000	$4,500	81	$364,000
		Total Savings	**$800,000**

Conclusions

Results of this test were very favorable, indicating that a tilling system will provide significant cost savings if used under favorable weather conditions and in the right configurations. Further use of mechanical clearance technology should be encouraged on projects where anomaly counts are high and where MSDs will allow safe operation.   The lessons learned during this test will be useful in future applications of this and similar mechanical methods for UXO clearance.